United States Military Academy
West Point, New York 10996

A Methodology for Base Camp Site Selection and Facility Layout

OPERATIONS RESEARCH CENTER OF EXCELLENCE
TECHNICAL REPORT #DSE-TR-02-1

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14. ABSTRACT
In the decade since the end of the Cold War, the number of Support and Sustain Operations (SASO) or Operations Other Than War (OOTW) conducted by the United States has greatly increased. The current trends show no signs of changing, so service members can expect to spend a significant portion of their careers performing peace enforcement, peacekeeping, humanitarian assistance, and disaster relief missions throughout the world. To maintain a deployed force conducting such potentially lengthy operations, semi-permanent basecamps are required to provide the needed unit and soldier support facilities. Despite their obviously important role, there is little to no doctrine, (especially for the United States Army) to determine where a basecamp should be sited geographically or how it should be laid out. This research outlines an integrated methodology to help military commanders and planners decide first, where to place basecamps and second, how to layout those basecamps.

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Executive Summary

In the decade since the end of the Cold War, the number of Support and Sustain Operations (SASO) and Operations Other Than War (OOTW) conducted by the United States (U.S.) Army (and entire military by extension) has greatly increased [Ezell]. The current trends show no signs of changing, so soldiers in today's Army can expect to spend a significant portion of their careers performing peace enforcement, peacekeeping, humanitarian assistance, and disaster relief missions throughout the world. To maintain a deployed force conducting such (potentially lengthy) operations, the Army has begun constructing semi-permanent basecamps. These camps provide logistical storage, maintenance areas, and soldier support facilities. Despite their obviously important role, there is little to no Army doctrine to determine where a basecamp should be sited geographically or how it should be laid out. The goal of this research is to develop an integrated methodology with a two-fold goal: to help military commanders and planners decide first, where to place basecamps and second, how to layout those basecamps. This executive summary discusses the highlights of the methodology that has been developed to better site and layout basecamps in support of SASO/OOTW.

Critical to this methodology are accurate geographical information products. Whether paper maps or digital terrain files, some geographical information product that closely reflects the terrain under consideration's actual characteristics must be utilized. In this research, several geographical information formats were examined, but the methodology presented is discussed from the vantage of having used standard military 1:50,000 scale maps.

First, the site-selection portion of the methodology is addressed. Originally, a robust, mutually exclusive and collectively exhaustive values hierarchy was constructed to structure those issues important in selecting a site. However, this values hierarchy was deemed to be too cumbersome for operational use by several military commanders and planners who reviewed it during a military conference [Wohlschlegel]. While the values hierarchy is a useful tool for risk mitigation and planning, it gave way to a boiled down fundamental objectives hierarchy that includes only those seven objectives that truly drive the evaluation of a candidate site's suitability to support a basecamp. Coupled with an initial screening process, the fundamental objectives hierarchy provides the bulk of the tools needed to evaluate alternative sites.

The fundamental objective hierarchy measures a candidate site's value by looking at the following seven attributes of the site: 1) size of the site available; 2) air access (air avenues of approach); 3) road access (ground avenues of approach); 4) slope; 5) amount of foliage present; 6) distance to a water source; and 7) distance to the mission area.

Using Multi-Objective Decision Analysis (MODA), a commander or planner can evaluate each site based on these seven evaluation measures, the weights placed upon each of the seven, and the value functions used to represent preference within each of the seven areas. This MODA approach allows commanders and planners to better represent personal preferences or mission requirements. Again, prior to evaluating any candidate sites, a set of screening criteria that are described later in this report can be used to ensure that completely undesirable sites are eliminated from consideration. Such sites include minefields, protected wetlands, critical economic centers and the like. This screening process is part of a larger Intelligence Preparation of the Battlefield (IPB)-like process that is designed to remove or identify the grossly undesirable portions of the terrain under consideration.

Alternatives are generated using the IPB guidance provided in the site selection portion of the methodology. The alternatives are then compared to the set of seven criteria above to determine a site's overall value. Using an Excel-based Decision Support System (DSS) the sites are then rank-ordered in order of decreasing value, so that each one can be further explored to verify if and how it might support a basecamp. This second process, the site layout portion of the methodology, incorporates some portions of the original site selection methodology as well as a new process for analyzing terrain and laying out a basecamp's facilities. During the facility layout portion, a more detailed IPB is conducted to identify any small additional portions of the alternative that may influence the layout.

The site layout portion of this methodology is the product of interviews and discussions with several U.S. Army and coalition commanders and planners [Ezell, McClure, Wohlschlegel]. Designing an actual basecamp layout and marrying it to a parcel of terrain is part science and part art.

The science aspect consists of the actual basecamp layout that is best determined to ensure that facilities that belong together are together, that facilities that do not belong together are not together, and that those facilities that have no relationship are not allowed to overly constrain the problem. Later in this report, a doctrinal template (basecamp layout) constructed

from U.S. Army experience and field research in the Balkans is presented. The science of basecamp layout is further extended through the use of a simulation tool, Promodel, in which one large U.S. basecamp in Kosovo, Camp Bondsteel, was modeled. Improvements in Camp Bondsteel's layout can be measured through such statistics as queue lengths, customer service times, and other flow-related statistics at various points around Camp Bondsteel. Minimizing total flow on Camp Bondsteel is the major objective as the layout with the least flow ensures that those entities (facilities) that should be nearest each other are, without forcing together those entities that do not belong together. The comparison begins by first gathering simulation statistics on the doctrinal template (or Camp Bondsteel as it actually is laid out). Then making a change(s) in the layout and recollecting the statistics provides two sets of statistics whose differences hint toward gains or losses in effectiveness or efficiency.

The art aspect is taking this ideal doctrinal template and fitting it to the actual site using a set of heuristics. These rules of thumb can be traced to force protections requirements or common sense practice as developed over decades of building base camps. Again, simulation can be used to assist commanders and planners determine the impact of such rules of thumb.

Basecamps will continue to play an important role in U.S. Army operations in the Twenty-first Century as the Army takes on more SASO and low-intensity missions throughout the globe. This technical report is designed to contribute to the practice of building basecamps and to the effectiveness of such basecamp locations and layouts. Section 3 outlines the process recommended in selecting sites and laying out basecamps.

Initial indications from field research in the Balkans (Croatia, Kosovo, and Macedonia) are that the U. S. military is doing an adequate job of choosing good locations for the majority of its basecamps (especially the big ones like Camp Bondsteel), but in many cases the best locations aren't being selected. This report provides a process through which the U.S. military can select the best sites possible, arrange the sites as best possible, and then defend the selection and design of the site as "the best" according to the proposed metrics.

About the Author

Captain Frank J. Snyder earned a Master of Science Degree in Systems Engineering and a second Master of Science Degree in Urban Systems Engineering (Civil, Infrastructure, and Environmental Engineering) from George Mason University in 2000. He earned the Bachelor of Science Degree in Systems Engineering from the University of Virginia in 1992. He currently serves as an assistant professor and operations research analyst in the Department of Systems Engineering at the United States Military Academy at West Point. His teaching and research focus on decision analysis and multi-objective decision analysis. He is a member of several professional organizations including the International Council on Systems Engineering (INCOSE), the Armed Forces Communications and Electronics Association (AFCEA), the Military Operations Research Society (MORS), and the Phi Kappa Phi Honor Society.

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Section 1. Problem Definition

1.1. Definition of a Base Camp

The definition of a base camp has been a minor, but recurring issue in the continuum of research on basecamp design. It has been well documented that the term *basecamp* does not exist in the military literature, but that it is commonly used in the military. Following the working definition of *basecamp* offered following past research in basecamp design [Ezell, 2000], the following updated definition is provided:

> ***An evolving tactical facility that supports the military operations of a deployed unit and provides the necessary support and services for sustained operations.***

1.2. Background

While the construction of bases or posts in support of military operations is nothing new, the change in number and frequency of Support and Stability Operations (SASO) or Operations Other Than War (OOTW) relative to war operations has. The result of such change has been a greater need for a greater quantity of semi-permanent encampments in which traditional concerns in choosing locations to build upon have shifted from strictly tactical ones. The choice of location for bases now includes concerns for available infrastructure, quality of life for deployed soldiers, and impact on host nation.

It is more important now than ever to ensure that when basecamps are constructed, they are placed and laid out as wisely as possible for several reasons. The reason that looms largest is that the number of OOTW commitments have increased so dramatically, that economies of scale (the number and frequency with which the U.S. conducts OOTW [Ezell, 2000]) promise to allow the U.S. to make tremendous savings in effectiveness and inefficiency or to suffer tremendous losses in those two areas. OOTW are no longer those occasional operations that detract from the U.S. military's other missions. Now, rather, OOTW are a staple of military missions and must be treated as such and backed with doctrine, techniques, tactics, and procedures. Again, this demonstrates the impetus for the research.

1.3. Effective Need

The effective need is the unifying statement that reshapes the primitive need of the client or sponsor for whom this research is undertaken. For the Basecamp Design research effort, the effective need is:

> ***To design a methodology that assists military commanders and planners in choosing sites on which to build basecamps and in determining how to arrange (or layout) those facilities that constitute the basecamp.***

1.4. Stakeholder Analysis

The list of stakeholders in a problem this large can be quite lengthy. The list can be decomposed for better clarity according to whether a stakeholder is a sponsor, client, decision maker, user, bystander, or analyst.

The sponsor is the stakeholder who pays for the research conducted. Often the sponsor is the client and a distinction is not drawn between the two classes of stakeholders. The sponsor for this research is the Department of Systems Engineering (DSE) at the United States Military Academy. However, the United States Army Corps of Engineers has expressed interest in perhaps fulfilling this role in the future.

The clients are the stakeholders for whom the research is conducted. The main client in this research is Colonel Robert L. McClure who was the lead engineer for the Camp Bondsteel construction effort. Additional clients in this research are the unified command elements and deployed units.

The decision maker is the stakeholder who will actually have a say in whether or not or how this methodology is implemented. This group of stakeholders is hardest to define, but can be traced from (and including) the National Command Authorities down through and including the unified combatant commanders, planners, engineers, and junior commanders. Additionally, the list of decision makers can incorporate peer or coalition organizations such as the North Atlantic Treaty Organization (NATO) or the European Union (EU).

The users are the class of stakeholders that move through the system and have at least some say in how the system operates. In this research, the users are the deployed units and soldiers, principle staff agencies, contractors, Non-governmental Organizations (NGOs), Private Volunteer Organizations (PVOs), and other similar groups.

The bystanders are the class of stakeholders that are in some way affected by the system at hand, but that have virtually (either none or so far removed to be of no consequence) no input into how the system operates. The bystanders in this research are the U.S. citizens/taxpayers and the inhabitants of the host nation in which the basecamp resides. Basecamps are usually placed in countries at the will of the host nation government or organizations such as NATO or the EU, so individual citizens of a country such as Bosnia-Herzegovina may have no say.

The final class of stakeholders includes the analysts who depend on the quality of the system to line their coffers or build their reputations. The list of these stakeholders is a virtual mirror of those highlighted on the acknowledgements page of this technical report.

Section 2. Value Structure

2.1. Fundamental Values for Site Selection

In this chapter, both a thorough values hierarchy and a refined fundamental objectives hierarchy are presented for those things that matter in selecting a basecamp location. The value hierarchy has both an academic and an operational value. From an academic standpoint, the values hierarchy captures and structures all (collectively exhaustive) of the values in a way that avoids duplication (mutually exclusive). From an operational standpoint, the values hierarchy provides a powerful risk management tool by suggesting those areas in which some measure of attention should be shown or some plan should be created. However, there is one operational shortcoming of the values hierarchy. Operational commanders and planners have reviewed and applauded the hierarchy on its thoroughness, but dubbed it too cumbersome for operational use.

The fundamental objectives hierarchy represents a small subset of the greater values structure that are particularly useful in selecting a base camp location. Both such hierarchies are presented in this chapter for completeness.

2.1.1. Values Hierarchy

Lieutenant General (LTG) Robert Flowers, Chief, the United States (US) Corps of Engineers, provided initial direction to this Base Camp Design Research effort during a meeting with the Operations Research Center on 2 May 2001. LTG Flowers said "If you can figure out the criteria for base camp selection, then you've done something that the Army can use."

Determining the values, those things that matter in choosing where to place a base camp, is a non-trivial task. Little to no doctrine exists on choosing where and how to layout a base camp. In this section, the values for choosing a site upon which to build a base camp are explored. The base of knowledge in this area exists largely in the minds of those who have spent a career gaining the knowledge through experience. Codifying these values is an important first step that serves two main purposes. First, the right set of values should capture the fact that the nature of basecamps used to support deployed military forces has changed in the last decade. The bulk of such facilities no longer support missions of war, but rather operations other than war (OOTW), also called Support and Stability Operations (SASO). Second, the right set of values should capture those values that traditionally have been overlooked or under-considered:

the importance of quality of life for deployed soldiers (indirectly captured in space considerations to ensure a site offers sufficient room to bring in an acceptable complement of soldier support items), the impact on host nations, and the availability of sound infrastructure.

Because of the breadth and depth of the values hierarchy, it is decomposed below and shown in several pieces. The upper level of the hierarchy appears as shown in Figure 1.

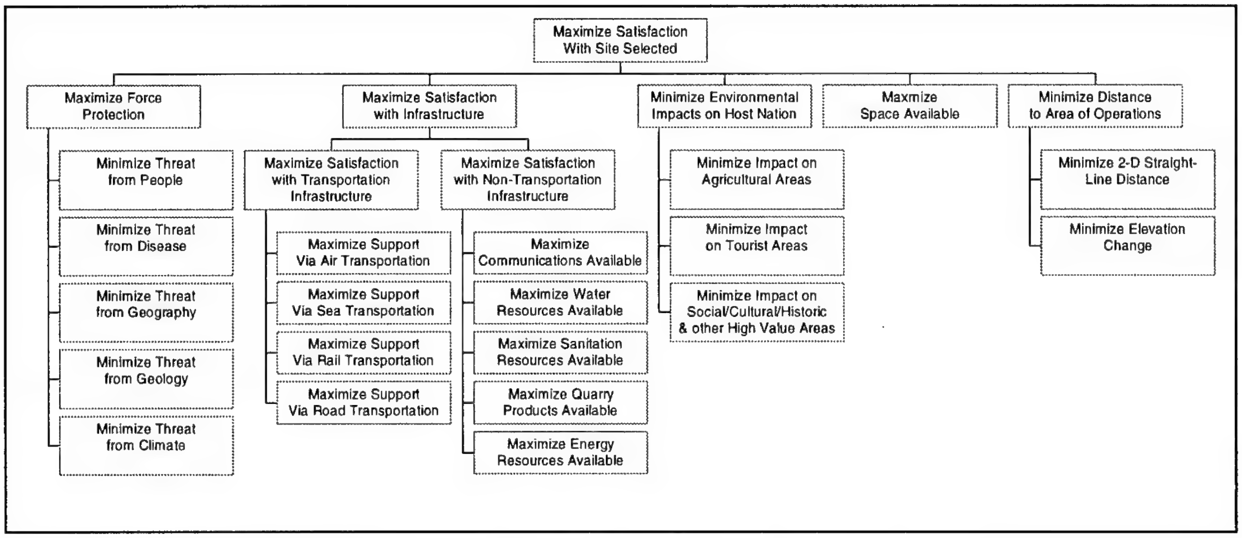


Figure 1: Values Hierarchy (Upper Level)

Notice in Figure 1 that, in order to maximize satisfaction with the overall site that is selected, it is important to maximize force protection (a traditional military value applicable to war, OOTW, and peace), to maximize satisfaction with infrastructure (a non-traditional value more applicable to base camps under OOTW), to minimize environmental impacts on host nations (also a non-traditional value more applicable to base camps under OOTW), to maximize space available (a traditional value with a modern view toward ensuring that space exists to meet mission and quality of life interests), and to minimize distance to area of operations (a non-traditional value that suggests in OOTW, there maybe some acceptable tradeoffs among force protection and mission effectiveness concerns). At the terminal ends of the values hierarchy, each remaining criterion could be measured via some natural or constructed scale. Because this values hierarchy is not actually used to measure the alternatives (the fundamental objectives hierarchy is so used), these value functions, scales, and weights have not been fully developed.

However, the manner in which some of these could be measured is intuitive. An example of one of the scales is provided following Figure 4.

In Figure 2, all of those areas in which force protection is of concern are decomposed. Notice, the hierarchy is decomposed according to the source of the threat. Some of these threats are also far less significant than others. This could easily be modeled through the relative weights that would be assigned to these values and objectives during analysis.

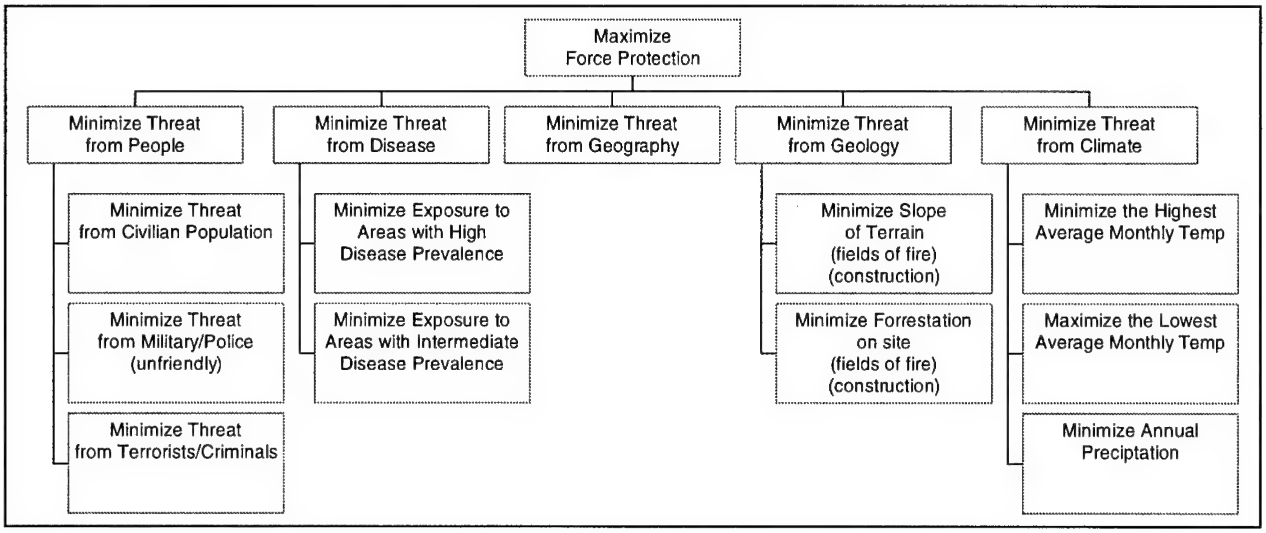


Figure 2: Values Hierarchy (Force Protection Branch)

In **Figure 3**, the hierarchy displays all of the areas in which transportation infrastructure has an impact upon the decision. For the most part, the transportation infrastructure concerns are broken down according to which mode the transportation takes place (air, sea, road, or rail). Also, for the most part, each type of transportation has three facets: quality, quantity, and proximity. For quality, the question is, “how good are the facilities that support transportation in that medium?” For quantity, the question is, “how much of it can I get?” For proximity, the questions is, “how close is it?”

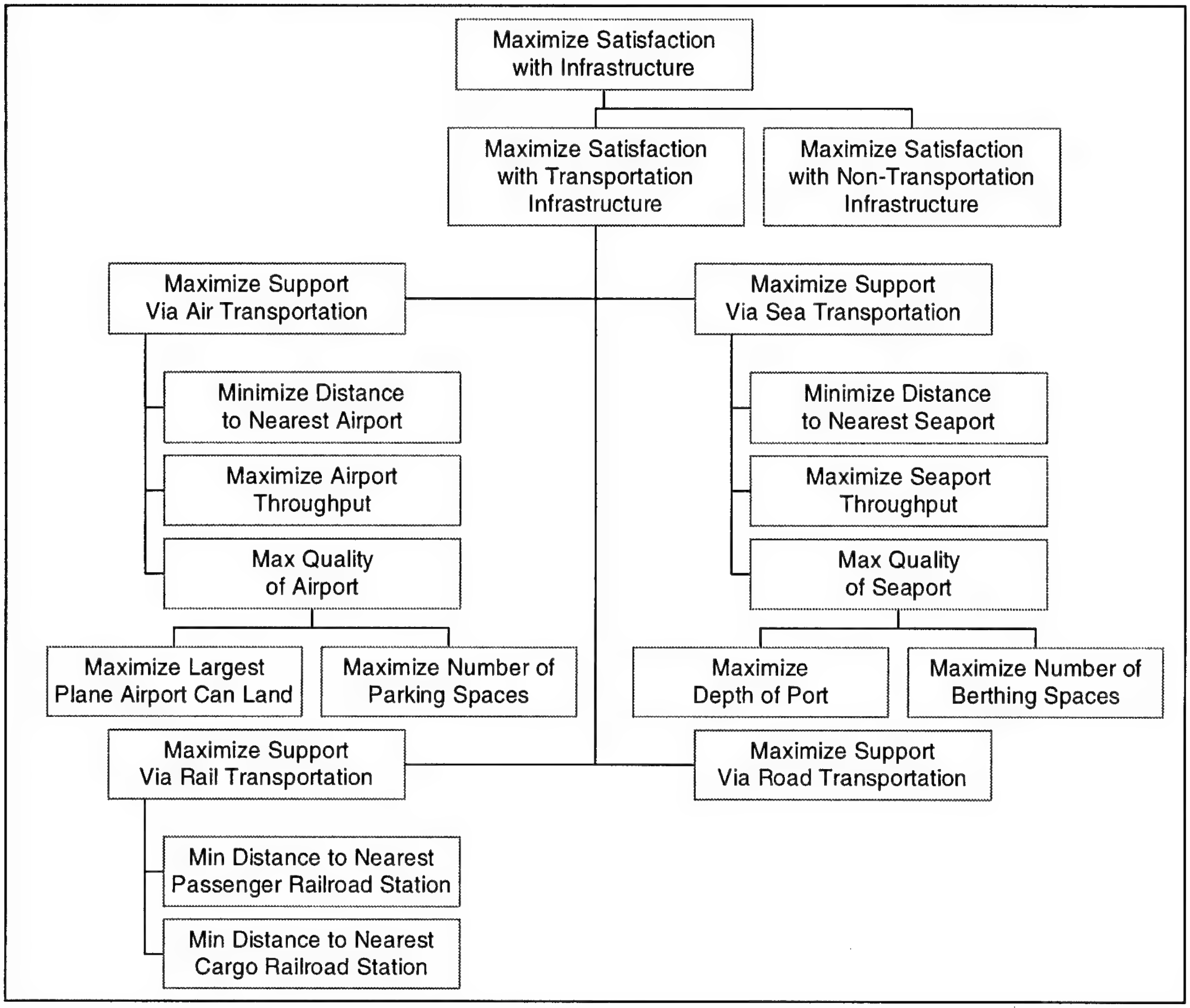


Figure 3: Values Hierarchy (Transportation Infrastructure Branch)

In Figure 4, the non-transportation infrastructure values are shown fully decomposed. Although, the U.S. Army is likely to meet its own infrastructure needs by bringing its own communications assets or by flying in its own water (provided as examples), this hierarchy helps to determine where the U.S. Army can safely augment its resources (such as local phone lines).

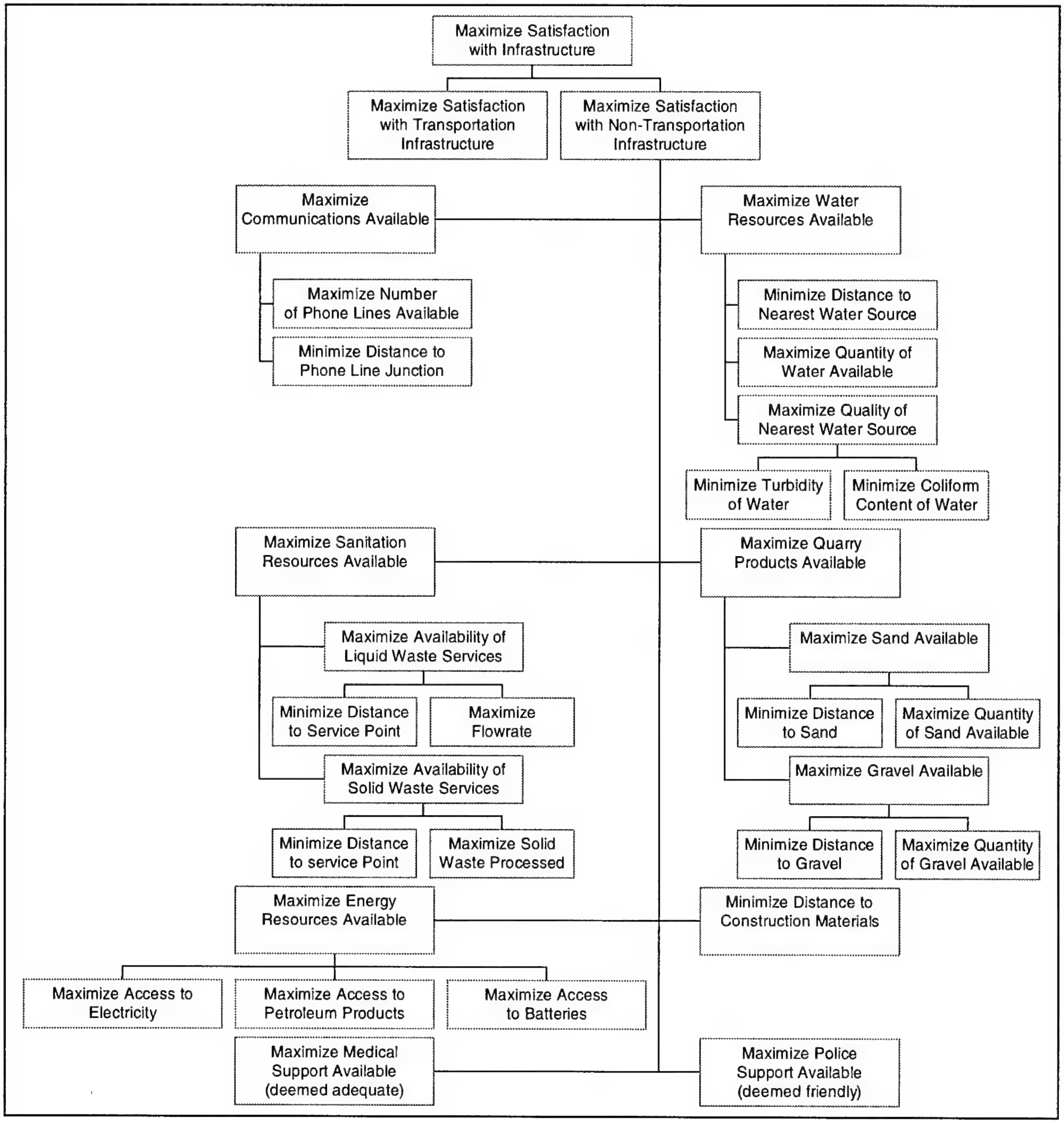


Figure 4: Values Hierarchy (Non-Transportation Infrastructure Branch)

Also, detailed values hierarchy, like that shown in Figure 4 helps to identify the potential areas of risk by helping planners ask questions such as "Where are we going to get our gravel and sand for construction purposes?" after reading the hierarchy.

For completeness and to demonstrate the level of complexity involved in accurately measuring a large number of alternative attributes, an example of what a measurement scale might look like for the *Maximize Quality of Nearest Water Source* branch of the hierarchy is provided below in the following two paragraphs. Originally detailed measurement scales were pursued for all of the value Hierarchy terminal ends, but before the process was complete (some scales had not yet been constructed and some proxies had not yet been chosen), feedback on the value hierarchy indicated it was too cumbersome to use operationally and that a subset of the most important evaluation measures should be considered. The *Maximize Quality of Nearest Water Source* branch is subdivided into *Minimize Turbidity* and *Minimize Coliform Content* [Cornwell, 1998].

Turbidity is a physical characteristic of water and is defined as, "The presence of suspended material such as clay, silt, finely divided organic material, plankton, and other particulate material in water. Turbidity is measured in Nephlometric Turbidity Units (NTU) in which a score of 0.5 NTU or greater in 95% of samples taken equates to water being deemed impure [Cornwell, 1998]. If this evaluation measure were to be used, the scale for turbidity (less is better) would be based on the average # of NTUs for some number (approximately 20) samples.

Coliform content is a measure of the amount of microorganisms that exist in water that are capable of causing sickness or death in mammals [Cornwell, 1998]. A water source is deemed not fit for consumption if 5% of at least 40 water samples collected per month detect coliform. If this evaluation measure were to be used, the scale for coliform would be based on the percent of a set number of water samples testing positive for coliform.

Again, turbidity and coliform are only provided for completeness and to provide an appreciation of how quickly the values that matter can become complicated when moved from the theoretical to the operational. Expecting a planning staff to accurately obtain this much information on several sites quickly when selecting where to put a base camp is probably too difficult as evidenced by the feedback received on the values hierarchy. The fundamental objectives hierarchy was designed to remedy this.

2.1.2. Fundamental Objectives Hierarchy

The Fundamental Objectives Hierarchy is shown below as Figure 5. Coupled with the robust screening process and the specific guidance that can be expected from operations orders, commanders' guidance, etc., the fundamental objectives hierarchy captures those values that matter most in selecting a site for a basecamp [McClure and Cadicamo, 2002].

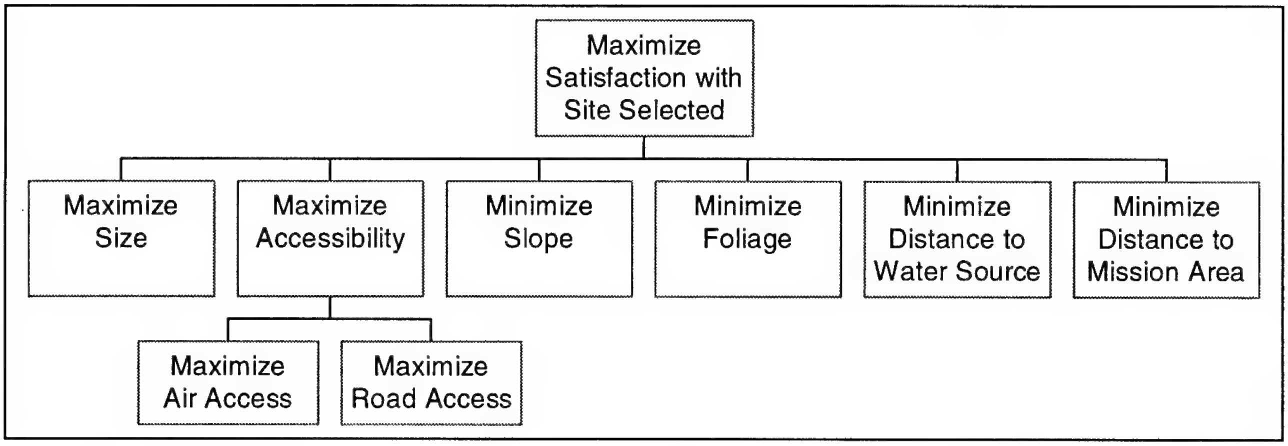


Figure 5: Fundamental Objectives Hierarchy

The scales for each of these criteria are completely enumerated in Section 3 of this technical report.

2.2. Fundamental Values for Facility Layout

The fundamental values for facility layout are not as well codified because an analytical approach to determining layouts is not believed to be appropriate. As a starting point, a doctrinal template (shown in Figure 6: Doctrinal Template for Site Layout) was created based on the input of SMEs and years of experience building basecamps around the world. Simulation, specifically ProModel, was used to help determine what a good layout is.

The values and subsequent objectives considered in the layout of facilities pertained to those that minimized flow, minimized waiting time, and minimized service time at the different facilities that compose a base camp. Minimizing total flow on Camp Bondsteel is the major objective as the layout with the least flow ensures that those entities (facilities) that should be nearest each other are, without forcing together those entities that do not belong together.

Section 3. Site Selection and Facilities Layout Methodology

The following annotated outline conveys the methodology that is recommended for siting and selecting base camp facilities.

3.1. Site Selection Phase

3.1.1. Identify the assigned mission area – The mission area for which the base camp is being designed to support must be considered in the initial phase to ensure that the site is geographically placed in a way that supports accomplishment of the mission. Planner guidance on mission area location, required proximity to mission area location, and size of base camp(s) should be obtained from the following sources:

3.1.1.1 Commander's Guidance

3.1.1.2 Staff Estimates

3.1.1.3 Host nation constraints

3.1.1.4 Mission analysis

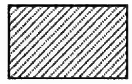
3.1.1.5 Specified planning factors (such as "the base camp must be within 30 km Euclidean distance of the mission area")

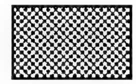
3.1.1.6 Non-governmental resources (the Central Intelligence Agency Factbook)

3.1.2. Conduct Intelligence Preparation of the Battlespace (IPB) for the Area of Interest (AI) – IPB at this level should be considered macro-IPB in that the details of the larger AI are considered and not the specific details of the smaller individual sites. Later in the methodology, the site details will be considered during a process that will be called "micro-IPB."

3.1.2.1 Screening Phase (General) - Eliminate an alternative if it fails any of the conditions discussed in this part (Part B) of the methodology– If any portion of a 1 km x 1 km grid square fails any of the conditions below, then the entire grid square should be eliminated. This is done within reason since maps can be flawed or out of date. Sound judgment must be shown in determining what can be screened out. While screening criteria can be loosened later if required,

the grid square can also be eliminated later if need be during micro-IPB. To graphically portray restrictions on maps, terrain is shown as either *restricted* or *severely restricted* is shown so on maps with the following patterns in "red":





Restricted Severely Restricted

3.1.2.2 Land Availability – The land is unobtainable and therefore "severely restricted". For example, the owner won't rent the parcel of land desired.

3.1.2.3 Force protection concerns – Terrain with the following characteristics should be considered *severely restricted*:

- Disease Infested Regions
- Urban Areas (crime, terrorism, demonstrations prone)
- Mined areas
- Flood Plains (Perhaps 25 year or less frequency)
- High altitudes (colder environment, thinner air, avoid constant up/down)
- Swamps, bogs, wetlands
- Waste dumping sites (Including hazardous material)
- Unstable ground (karst terrain, geographic faults, etc)

3.1.2.4 High Value Land – This terrain should be considered *severely restricted.*

- Critical Agricultural Land (Economic concern)
- Critical Industrial Facility Land (Economic concern)
- Cemeteries (Social/Religious concern)
- National Parks/Preserves/Protected areas (Social concerns)
- Tourist Areas (Economic concern)
- Hospitals (Key infrastructure)
- Religious Sites (Religious concern)
- Schools (Key infrastructure)

3.1.2.5 Operational Concerns – This terrain should be considered *restricted* or *severely restricted* based on an assessment of the items below. If the terrain fails both the steepness and foliage concern, then it should be considered *severely restricted.* If it fails only one, then a decision must be made regarding the acceptability of the steepness of the terrain (constant slope or sheer cliff) and on the forestation (small pockets of immature forest like small pines or several square kilometers of mature forest like oaks.) Further guidance is given below:

3.1.2.5.1 Steepness – Terrain that has a slope of 8% or less is acceptable for construction. During macro-IPB, terrain with twice this slope (16%) or less will not be screened because some actions can be taken to reshape the terrain. Terrain possessing a slope greater than 16% will be screened out as *severely restricted* from a construction standpoint. Terrain having a slope in the range of 8-16% will be marked as *restricted*, but not screened out completely in macro-IPB. The slope of terrain will be evaluated by grid square with an entire grid square being eliminated in the event of any slope greater than 16%. Slope is calculated by dividing the change in elevation by the straight-line distance between two points on the ground (i.e. slope = rise/run). Further, hilltops and depressions will not be used in calculating slope as they are screened out as undesirable by the next two bullets below. The grid square is shown as *restricted* or *severely restricted* if **any two points** in that grid square that wasn't eliminated possess the degree of slope described in this section.

3.1.2.5.2 Hilltops – screen out as potential construction sites for base camps even though they may eventually be useful for establishing line of site communications.

3.1.2.5.3 Depressions - screen all from consideration.

3.1.2.5.4 Densely wooded or covered in large foliage – All heavily wooded areas will be considered severely restricted in the initial analysis.

3.1.3. Draw potential area boundaries

3.1.3.1 General Considerations

3.1.3.1.1. Identify planning guidance provided on base camp area location(s), proximity to mission area, and size from those sources listed above.

3.1.3.1.1.1. Following IPB, a great deal of terrain in the AI should remain feasible for placing base camps. If not, it will be necessary to loosen the screening criteria until some terrain is available for consideration.

3.1.3.1.2. Number of alternatives – In order for a decision to be made, there must be at least two alternatives (sites) to consider. In general, a better decision can be made with more alternatives. Evaluate as many alternatives as available, but certainly generate several times as many alternatives as sites needed, if possible. Also following analysis or additional insight, consider creating hybrid alternatives from the existing ones, if feasible.

3.1.3.1.3. Size considerations in drawing boundaries – When drawing the areas, IPB has only been conducted with respect to the larger area of interest and not down to the specific site, or area of operations. Therefore, the following planning factors are suggested to ensure that the sites will be sufficient for laying out a base camp after more detailed IPB (tighter constraints) are applied to the individual sites. These planning factors are 1.5 times greater than actually needed and listed below [McClure, 2002]. This helps to ensure at this step of the analysis that the candidate sites will be large enough to support a base camp of a specified size when the individual sites are scrutinized in more detail in latter steps of this methodology.

3.1.3.1.3.1. Large base camp (like Camp Bondsteel): supports at least a Brigade; requires approximately 1500 acres (6 km^2).

3.1.3.1.3.2. Medium base camp: supports at least a Battalion; requires approximately 750 acres (3 km^2).

3.1.3.1.3.3. Small base camp: supports at least a company; requires approximately 375 acres (1.5 km^2).

3.1.3.2 Procedure – Identify areas that have the following characteristics and draw the boundaries of potential areas to maximize their effectiveness with respect to size considerations.

3.1.3.2.1. Generally flat – Check the scale on the map, but ensure that contour lines are not shown close together and that the slope is not greater (in general) than 8% (reference: COL McClure email).

3.1.3.2.2. Not inclusive of more than 50% terrain covered by foliage (trees or large shrubs) that was determined to be *restricted* or *severely restricted* - Reasons may exist for having to include blocks of *restricted* or *severely restricted* terrain in a site such as access to a major road. Building a road through restricted terrain may prove to be a minor effort that affords access to a superior road. Additionally, while undesirable for many reasons, the shape of terrain and its degree of forestation can always be changed. In designing base camps, one goal is to minimize the changes to the environment.

3.1.3.2.3. Near water sources - While wells are always an option, sites that include or are near rivers and lakes are of high value.

3.1.3.2.4. Access – Draw boundaries so that sites have access to both ground and air avenues of approach. A site should be relatively close to both. Higher quality and capacity roads are better for ground approach. When drawing boundaries, high quality and high capacity roads should be utilized as boundaries since they provide exceptional ground connectivity. However, only secondary roads or roads that are not depended on by the local population for commerce or daily travel should be included on a base camp where access will be limited. For air avenues of approach, better sites have limited trees, power lines, prominent terrain features in the third dimension, or other obstructions to landing and take-off paths. This process focuses on air avenues of approach for rotary wing assets, but could easily be expanded to include fixed wing assets as well. Few

modern base camps will be built to accommodate fixed wing aircraft; instead, host nation infrastructure will be depended upon for this capability [McClure, 2002].

3.1.4. Evaluation Phase – Once a set of alternatives or candidate sites has been generated, they can be evaluated to determine what the preferred rank ordering of them is. The value structure below enumerates the (virtually) exhaustive list of concerns, while the fundamental objectives hierarchy enumerates the subset of evaluation measures that research has determined drive the site selection decision.

3.1.4.1 Evaluation Measures

3.1.4.1.1. Value Structure (everything of interest) – This methodology presents a robust value structure that incorporates everything that is believed to be of interest in making the decision regarding where to site a base camp. However, this methodology is too cumbersome to be of operational use. It contains approximately 50 evaluation measures that serve best to help identify the potential risks of siting a base camp. This value structure is an excellent tool for suggesting what additional mitigation strategies might be required to better site a base camp or to address the shortcomings of the site eventually chosen. It appears in complete form in other portions of this technical report.

3.1.4.1.2. Fundamental Objectives Hierarchy – This captures only those evaluation measures that should be used to select a site. Each is defined in more detail in other portions of this technical report.

3.1.4.1.2.1. Size (more is better; natural scale: acres or sq km with sq km being preferred). To convert acres to square meters, multiply by 4,046.856, and bear in mind that 1 km^2 = 1,000,000 m^2.

3.1.4.1.2.2. Access (separate constructed scales for road and air access). This evaluation measure is best partitioned in to two measures, air access and road access:

3.1.4.1.2.2.1. For air access (more is better, it is a constructed scale based on the proximity to air obstacles), the foliage evaluation measure already partially accounts for fewer trees being preferred, so there is some potential, but acceptable overlap in the evaluation measures on this point. Trees (specifically, large densities of mature forest) are one of the major air obstacles in which more stand-off distance is preferred. The remaining concern for air access is stand-off distance from other air obstacles such as power lines, odd geographic formations (such as mesas), tall buildings (or urban areas where lots of buildings are located), bird breeding or nesting grounds, or anything else that occupies airspace. Examine available information (especially the map) regarding the alternative in question. The constructed scale for this evaluation measure is as follows (all returns to scale are assumed to be linear):

3.1.4.1.2.2.1.1. If an alternative's geographic center is 0-0.5 km from an identified air obstacle, it scores is 0.

3.1.4.1.2.2.1.2. If an alternative's geographic center is 0.5-1.0 km from an identified air obstacle, it scores is 1.

3.1.4.1.2.2.1.3. If an alternative's geographic center is 1.0-1.5 km from an identified air obstacle, it scores is 2.

3.1.4.1.2.2.1.4. If an alternative's geographic center is 1.5-2.0 km from an identified air obstacle, it scores is 3.

3.1.4.1.2.2.1.5. If an alternative's geographic center is 2.0-2.5 km from an identified air obstacle, it scores is 4.

3.1.4.1.2.2.1.6. If an alternative's geographic center is 2.5-3.0 km from an identified air obstacle, it scores is 5.

3.1.4.1.2.2.1.7. If an alternative's geographic center is > 3.0 km from an identified air obstacle, it scores is 6.

3.1.4.1.2.2.2. For road access, more access to better roads is preferred. Some sites will have more than one road as a border or through the site. To properly value the existence of more than one road supporting a site, an alternative (site) will be scored by summing the product of the number of kilometers of a road type and the score of the road type as shown below, for all roads supporting a site. The constructed scale is based on the road distinctions used on standard military 1:50,000 scale maps. The constructed scale (of road scores) for this evaluation measure is as follows (all returns to scale are assumed to be linear):

3.1.4.1.2.2.2.1. If a road is all weather, hard surface, and divided it scores a 7.

3.1.4.1.2.2.2.2. If a road is all weather, hard surface, and two or more lanes wide it scores a 6.

3.1.4.1.2.2.2.3. If a road is all weather, hard surface, and one lane wide it scores a 5.

3.1.4.1.2.2.2.4. If a road is all weather, loose or light surface, and two or more lanes wide, it scores a 4.

3.1.4.1.2.2.2.5. If a road is all weather, loose or light surface, and one lane wide, it scores a 3.

3.1.4.1.2.2.2.6. If a road is fair or dry weather and has a loose surface, it scores a 2.

3.1.4.1.2.2.2.7. If a road is nothing more than a trail or tracks (path) of some sort, than it scores a 1.

3.1.4.1.2.2.2.8. If no type of thoroughfare exists, it scores a 0.

3.1.4.1.2.2.3. Slope (less is better; constructed scale based on simple rise in elevation divided by straight-line distance between any two points in the same grid square.) Direction of slope is irrelevant. An average slope for each area is calculated by averaging the slope in the 3 to 6 grid squares that most closely represent the area under scrutiny. The analyst need not consider the same number of squares in competing sites (alternatives) because of the potential for each area to vary greatly in size and in size of unit it is capable of supporting. Again hilltops and depressions are ignored. Fractal Mathematics is being examined as another (better) way to ascertain value of terrain militarily. The constructed scale for this evaluation measure is as follows (all returns to scale are assumed to be linear):

3.1.4.1.2.2.3.1. If an alternative's average slope is 0-1%, it scores a 1

3.1.4.1.2.2.3.2. If an alternative's average slope is 1-2%, it scores a 2

3.1.4.1.2.2.3.3. If an alternative's average slope is 2-3%, it scores a 3

3.1.4.1.2.2.3.4. If an alternative's average slope is 3-4%, it scores a 4

3.1.4.1.2.2.3.5. If an alternative's average slope is 4-5%, it scores a 5

3.1.4.1.2.2.3.6. If an alternative's average slope is 5-6%, it scores a 6

3.1.4.1.2.2.3.7. If an alternative's average slope is 6-7%, it scores a 7

3.1.4.1.2.2.3.8. If an alternative's average slope is 7-8%, it scores a 8

3.1.4.1.2.2.3.9. If an alternative's average slope is >8%, it scores a 9

3.1.4.1.2.2.4. Foliage (less is better; constructed scale based on the percentage of an area that is wooded or shrubbed and requires clearing before it can be used). A site that has less foliage is better for force protection and requires less effort to prepare for building [McClure]. The percent of foliage should be estimated from available information (map) and not methodically calculated. The constructed scale for this evaluation measure is as follows (all returns to scale are assumed to be linear):

3.1.4.1.2.2.4.1. If an alternative is 0-10% covered, it scores a 1

3.1.4.1.2.2.4.2. If an alternative is 10-20% covered, it scores a 2

3.1.4.1.2.2.4.3. If an alternative is 20-30% covered, it scores a 3

3.1.4.1.2.2.4.4. If an alternative is 30-40% covered it scores a 4

3.1.4.1.2.2.4.5. If an alternative is 40-50% covered, it scores a 5

3.1.4.1.2.2.4.6. If an alternative is 50-60% covered, it scores a 6

3.1.4.1.2.2.4.7. If an alternative is 60-70% covered, it scores a 7

3.1.4.1.2.2.4.8. If an alternative is 70-80% covered, it scores a 8

3.1.4.1.2.2.4.9. If an alternative is 80-90% covered, it scores a 9

3.1.4.1.2.2.4.10. If an alternative is 90-100% covered, it scores a 10

3.1.4.1.2.2.5. Water source (closer is better; natural scale: kilometers). This is measured in straight-line distance from an alternative's estimated geographic center of mass to the nearest suitable water source (lake, river, etc.).

3.1.4.1.2.2.6. Distance to mission area (closer is better; natural scale: kilometers). This is measured in straight-line distance from an alternative's estimated geographic center of mass to the geographic center of the assigned mission area.

3.1.4.2 Decision analysis – The potential sites (alternatives) now need to be compared to the evaluation measures to determine how much value each provides. This is accomplished using a spreadsheet-based multi-objective decision model (See Figure 8 in Appendix C). Each alternative must be scored against the fundamental objectives hierarchy established above. Further, the evaluation measures in the fundamental objectives hierarchy must each be weighted so that they can eventually be used in an additive value function to assess the value of each alternative. For this methodology, the additive value function has the following form:

$$\mathbf{V(X_{size}, X_{access}, X_{slope}, X_{foliage}, X_{water}, X_{mission})} = w_{size}v_{size}(X_{size}) + w_{acccess}v_{access}(X_{access}) + w_{slope}v_{slope}(X_{slope}) + w_{foliage}v_{foliage}(X_{foliage}) + w_{water}v_{water}(X_{water}) + w_{mission}v_{mission}(X_{mission})$$

Where,

v_i = single dimensional value functions for all "i" evaluation measures. All value functions are linear and normalized across their range of values.

w_i = swing weights on all "i" evaluation measures

3.1.4.3 While any planner can score the alternatives, operational commanders (primary stakeholders) must provide guidance on weighting the evaluation measures. The swing weighting technique is the preferred method of determining weights [Kirkwood, 1997], but for operational speed, a commander might best use a simpler technique such as spreading 100 points. In this case, the commander would subjectively, but not arbitrarily assign the weights, giving the most points to that alternative deemed most important while ensuring they sum to 100 points (or 1 if increments of 0.01 are assigned). The product of decision analysis is a rank-ordered list of the sites (alternatives).

3.1.4.4 Transition to the facilities layout phase - By this step, sites have been identified, rank-ordered and are ready to be further analyzed through the facilities layout phase. This step represents a change in goal from site selection to facility layout. However, the additional analysis that happens in the next phase not only results in a site layout, but also a validation of the site selection. The two phases cannot be decoupled.

3.2. Facilities Layout Phase

Using the ranked list from the first phase of the methodology, the alternatives should be considered one at a time down the list until the requisite number of base camps are found that meet the requirements for both number and size of base camps specified.

3.2.1. Intelligence Preparation of the Battlespace (IPB) – Now that sites have been chosen, the individual sites must be scrutinized through an additional round of IPB (micro-IPB) that considers the issues of concern and evaluation measures in greater depth.

3.2.1.1 Elevation change analysis – Terrain that is too steep cannot be built upon, so this terrain must be shown as restricted in some fashion. Earthmovers such as bulldozers can be used to level terrain; however, land preparation is time consuming. Hilltops and other sharp changes in elevation not caught in macro-

IPB should be shown as restricted (judgment call on whether *restricted* or *severely restricted*) now.

3.2.1.2 Foliage analysis – Large, mature, densely wooded areas should be shown as *restricted* for the most part. If coupled with steep terrain show the terrain as *severely restricted.* In many cases, a judgment call must be made based on experience or additional information as to how to classify the terrain.

3.2.1.3 Water analysis – As a means of validation, simply ensure that the site in question can be supported by water (river, well, flown-in, etc.)

3.2.1.4 Accessibility Analysis

3.2.1.4.1. Air accessibility (Can helicopters land/Is the overhead clear?)

3.2.1.4.2. Road accessibility (Can vehicles drive in?)

3.2.2. Space Available Analysis (Planning Factors) – After each site undergoes more detailed scrutiny, a decision must be made as to whether or not it really will support a base camp, and if so, what size. Ideally, the site selection methodology presented in Phase I, should prevent the need to eliminate an alternative (site) this late in the process. However, in some operations, the site to which a unit is assigned may be predetermined and force a unit's planners to start with the facilities layout phase. In such cases, planners will have to demonstrate perhaps through the facilities layout phase why the site they were assigned is (in)sufficient. The planning factors for site selection (listed in section 3.1.3.1.3) are 1.5 times larger than those below and were developed to ensure that sufficient area was selected to allow a finer level of screening during micro-IPB while still leaving enough land to build on. The planning factors for the actual base camps to be built are as follows:

3.2.2.1 Large base camp (like Camp Bondsteel): supports at least a Brigade; requires approximately 1000 acres (4 km^2).

3.2.2.2 Medium base camp: supports at least a Battalion; requires approximately 500 acres (2 km^2).

3.2.2.3 Small base camp: supports at least a Company; requires approximately 250 acres (1 km^2).

3.2.3. Orientation of the Doctrinal Template and activity placement – The doctrinal template (appears as Figure 6) is the result of studying several base camps that have been built by the United States in the past decade or so [McClure]. The "doctrinal template" must be first oriented in a site to obtain the "situational template". This orientation can be measured in degrees as rotated clockwise around the center of the template (up to 360 degrees). For example, the doctrinal template as shown is at zero degrees. One possible orientation is 90 degrees in which the oval is rotated clockwise 90 degrees to resemble a football standing up on end. Following IPB, the doctrinal template is oriented in the remaining usable space to form the "situational template. The goal is toe to ensure the space is used wisely and that the doctrinal template is altered as little as possible.

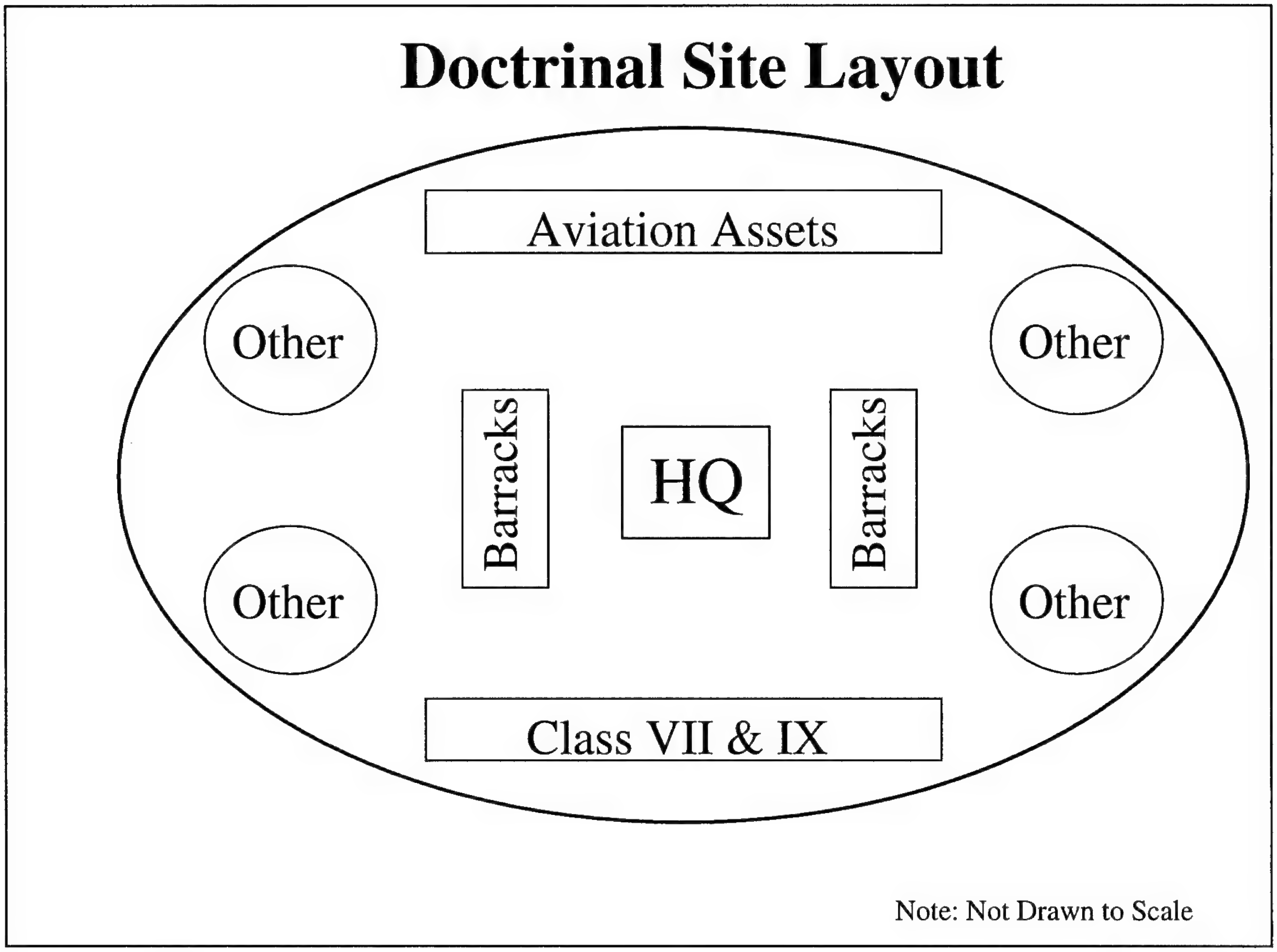


Figure 6: Doctrinal Template for Site Layout

3.2.4. Activity Placement - The following sequence of events describes how to orient the doctrinal template:

3.2.4.1 Aviation Assets – The placement of aviation assets is the key factor in orienting the doctrinal template for the following reasons:

3.2.4.1.1. Force protection – Because helicopters will often have uploaded munitions, the flight line must always occupy one of the edges of the base camp and must face outward.

3.2.4.1.2. Approach/Takeoff – A flight path must exist that does not force helicopters to fly over the base camp or near any hazardous aerial obstructions such as (trees, power lines, bird infested areas, etc.)

3.2.4.1.3. Roads – Because roads are a valuable component of all sites, it is important to avoid orienting the flight line in a way that forces the helicopters to face the road. Also, it is better to not have a major road right next to the flight line to protect lift assets from easy attack or damage.

3.2.4.2 Headquarters – Throughout time, military headquarters have always sought to locate themselves in such a way as to afford themselves the maximum amount of command and control over their forces. On a base camp, this continues to hold true. Often, headquarters elements are located as close to the geographic center of the base camp as possible. Central location does not equal command and control; however, so a decision will have to be made by the commander to determine where to place the headquarters.

3.2.4.3 Ammunition Holding Area (AHA) – For force protection reasons, the AHA and its Class V contents must be located away from other areas to minimize the consequence in the unlikely event it explodes or catches fire [USACE, 1990]. In the doctrinal template, the AHA must occupy one of the areas designated as "other" around the four corners of the site. On Camp Bondsteel, the AHA is an exaggerated teardrop in one of the corners that pushes well beyond the perimeter of a standard oval. This is the all-critical art piece of base camp site layout in which specific facilities are married to

specific pieces of terrain. Additionally, standard force protection planning factors often dictate space requirements between certain facilities such as the AHA and Petroleum, Oil, and Lubricant (POL) storage points.

3.2.4.4 Contractor areas – In the 1990's it has become evident that successfully base camp operations will involve partnerships between military and civilian organizations. In most cases, base camp construction and operations will involve large civilian contractors such as Brown & Root or DynaCorp. These contractors must be apportioned large pieces of the base camp so that they can conduct business. Contractor areas should be separated from military areas as much as possible for several reasons. For background, contractors at Camp Bondsteel are located at one of the corners of the base camp represented by the "other" blocks. Specifically, they are located nearest the main road and have an entire gate allocated to them because they transport and receive various supplies and materiel, continually. It is unwise from both force protection and quality of life perspectives to intermix contractor and military areas.

3.2.4.4.1. Force Protection – Placing contractors in an area where delivery trucks, contractor vehicles, earth movers, etc. must constantly drive through or near soldier support areas to accomplish their mission puts soldiers at risk unnecessarily from being hit by vehicles and from being exposed to the possibility of attack. The attack could take the form of everything from truck bomb, as it did at Khobar Towers in Saudi Arabia, to an individual person, who is posing as a contract employee, with a firearm.

3.2.4.4.2. Quality of life – Secondary concerns are the by-products that are common during a contractor's operations and maintenance phases of a base camp: noise pollution, poor aesthetics, trash, etc.

3.2.4.4.3. Rule of thumb – Primarily place contractor areas in the "other" block of a doctrinal template that is nearest road access and away from military (soldier support) areas.

3.2.4.5 Wastewater Treatment – If present or required, wastewater treatment facilities should be placed at one of the "other" blocks or at least significantly away from soldier support areas for a couple of reasons.

3.2.4.5.1. Quality of life – Nobody wants to smell a wastewater plant, landfill, or any kind of sewage in its various states of treatment. Therefore, these facilities should be sited away from soldier support areas.

3.2.4.5.2. Pumping considerations – Pumping has a high energy cost. Thoughtful placement (one that makes the most of gravity and natural terrain elevations) of a treatment facility, can save money. However, terrain can be sculpted to more accommodate a wastewater facility.

3.2.4.6 Company support areas – These areas include motor pools, arms rooms, orderly rooms, wash racks, and the like. Company work areas should be sited, so that they are conveniently located to soldier barracks. Moreover, scenario analysis (and perhaps simulation) can be used to trace the steps of various entities such as military patrols departing and arriving from the base camp to determine if the facilities that support them during departure and arrival are arranged in such as way as to best support them.

3.2.4.7 Soldier support areas – Soldier support areas include the post exchange, the barber shop, the education center, the chapel, laundry drop-off, movie theater, gyms, recreation facilities (pool tables, foosball tables, ping pong tables, etc.), and others should be placed near each other for soldier convenience. Additionally, they should be placed in reasonable proximity to the barracks. However, they should not be mixed in with certain areas such as barracks or the headquarters because lots of people who have business in the soldier support areas will not have business in the barracks or headquarters areas. As much as possible, it is wise to limit people's needs to access certain parts of a base camp. For example, on Camp Bondsteel, the American Post Exchange is open to members of the coalition countries on the weekends. While a foreign soldier may have a reason to enter Camp Bondsteel to shop the

post exchange and to get a haircut, he has no reason to walk through the barracks areas of soldiers who consider it home.

3.2.4.8 Other facilities – Several other facilities remain that must be sited on a base camp (hospital, dining facility, detention facility, guard towers, gates, etc.) These should be placed in such a way that they satisfy three rules of thumb:

3.2.4.8.1. Facilities that have a lot of flow of people or materiel between them or that have complementary missions should be placed together. For example, the laundry facility (or specifically the laundry drop-off point if different from the actual laundry facility) should be placed reasonably close to the two largest generators of laundry – the barracks and the mess facilities. This represents a high-flow relationship. Additionally, if the laundry drop-off point is different from the actual laundry facility, then placing the laundry facility near the waste water treatment facility has merit for obvious reasons (lots of waste water generated at laundry facility).

3.2.4.8.2. Facilities that have little flow of people or material need not be placed near each other. For example, one low flow relationship exists between the dining facility and the AHA.

3.2.4.8.3. Facilities whose location with another facility or general placement hinders mission, safety, quality of life, or any other force protection concern should not be placed together. For example, the hospital will little to no self defense capability, but will be required to operate while under attack. Therefore, the hospital should be placed near the center of the base camp, but certainly away from the perimeter.

Section 4. Sample Application of Site Layout Methodology

<u>Map Information</u>

Map Edition 3-DMA; Series M709; Sheet # 2285 II; Scale – 1:50,000

Area Covered by Map: Former Yugoslavia (Plaški, Croatia)

4.1. General Example Information

A map of the area, Area I, examined in this section appears below.

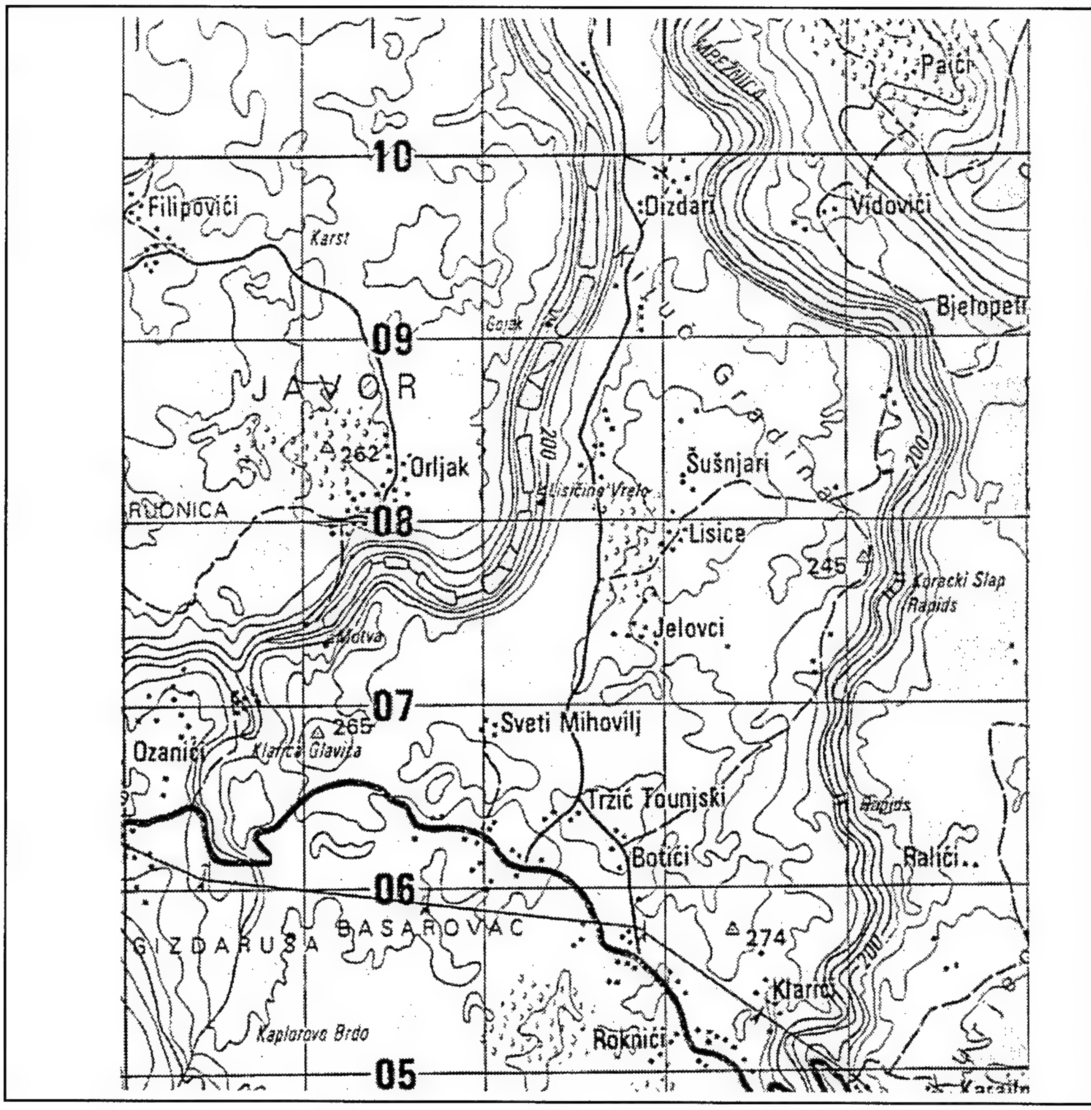


Figure 7: Map of Site "I"

This example demonstrates how a base camp might be laid out (assume the site has already been selected) in the several square kilometer area centered on coordinate 330070; bounded to the south by the two lane, improved road; bounded to the west by the series of lakes and river that become the Tounjčica River; bounded to the east by the Mrežnica River, and bounded to the north by the city of Dizdari which is located at the bottleneck formed by the two rivers approximately 1 kilometer from the edge of the map sheet.

4.2. Intelligence Preparation of the Battlespace (IPB).

The micro-IPB or site specific IPB can now be conducted for this candidate area. This candidate area was picked using the site selection phase of this methodology. In Section 3.2, the facilities layout portion of this methodology was presented.

Appendix B contains another example of how the facilities that compose a base camp might be laid out in other areas using the methodology presented in this report. These additional areas were identified in previous research and were not picked using the site selection phase of this methodology. However, the facility layout phase is applied to these areas as an additional tutorial to those who seek to use this methodology. Moreover, the comparison of the sites selected using this methodology (Section 3) and those not selected using this methodology, may unearth the potential value of the site selection portion of this methodology.

4.2.1. Elevation change analysis.

The area in question is bounded by one river to the east (elevation about 160 meters) and one river to the west (elevation about 160 meters). The banks of these two rivers rise quickly forming a plateau of rolling terrain at about 250 meters. The northern portion of the area is flatter than the southern portion. There are three benchmarks in the area. In the southwest, a hilltop named Klarica Glavica peaks at 265 meters. In the southwest, a benchmark can be found about 400 meters northwest of Klarići that records an elevation of 274 meters. In the central eastern portion of the area, the third benchmark sits just west of the Koracki Slap Rapids and reads 245 meters.

In general, the change in elevation is small and not greater than 20 meters within any one 1000-meter grid square. Therefore, this piece of ground is a good choice for a base camp location; that is the entire location should not be thrown-out as a potential site

due to grade. Some slope is absolutely necessary to ensure that the ground drains properly.

However, some specific areas of this terrain are not good for use within the base camp. Any area within approximately 200 meters of the riverbanks is bad because of the percent grade of the land heading toward the river. The areas near the benchmark in the southwest (265 meters) and the benchmark in the southeast (274 meters) are less attractive because the moderate elevation change in these areas would not facilitate quick construction. A fair amount of earthmoving activities or other mitigation effort would be required to prepare the land for construction.

4.2.2. Foliage Analysis

The entire area under consideration includes about 8-10 square kilometers. Approximately 1.5 square kilometers of this area is woodland and another 0.5 acres is scrub brush. The two main forested areas include the area north of Šušnjari (just right and up from the center of Figure 7) roughly bounded by (and including) the cities of Sveti Milhovilj, Tržić Tounjski, and Jelovci.

While the total area covered by woods or bushes accounts for 20-25% of the area, there remains a sufficient number of square kilometers to build a base camp. To avoid having to clear too much land at a great time and money cost, attention will have to be paid to the placement of the base camp facilities in relation to the wooded areas. Further, because clear land is associated with better force protection (in general), concern will have to be given to the threat posed by the mobility corridors and avenues of approach concealed by the wooded areas.

4.2.3. Water Analysis

This site is generously serviced by water from both the east and west. Aside from the possibility of dropping wells, it would be hard to site a facility that was not within at least 2 km of the water source let alone the distribution source. One fairly important consideration in analyzing the water sources at this site is the difference in elevation in

the site and the rivers. The site stands approximately 50 km's higher in elevation than do the rivers, so pumping costs (especially in terms of electricity) could be quite steep.

4.2.4. Accessibility Analysis

4.2.4.1 Air Accessibility

The site is about 80-85% not wooded, the two rivers are obviously without woods or other air impediment, and the site is largely flat (as discussed above). In the south of the area, the main road is virtually paralleled by a power line route that could serve as an impediment when landing helicopters. It will be important to avoid air avenues of approach into the site that bring helicopters too close to these power lines. Further, it is possible that the combination of the rivers, valley walls, and forested areas could attract a large number of birds. Care should be taken to avoid sending helicopters through bird-infested areas.

4.2.4.2 Road Accessibility

To the south, the area has approximately four kilometers of frontage along a two or more lane-wide, all weather, hard surface road. This provides the site an extremely generous amount of road accessibility and also will be key in determining the layout. Further, two fair (or dry weather) loose surface roads about a kilometer apart cut north off of the hard surface road and provide access into the area. These two loose-surface roads merge within a kilometer at Tržić Tounjski into a single fair, loose surface road. This single road heads due north along the western side of the area providing good access.

Also worthy of mention from this north-south loose surface road are two sets of trails that provide access into the center of the area. While they certainly are not likely to support large flows of traffic in their current state, they would require less clearing to make them suitable for traffic. The existence of this partial road infrastructure may certainly have some bearing on the placement of many base camp facilities.

4.3. Space Availability Analysis

Though there are patches of wooded areas scattered throughout the central area of this site, these areas have been classified as *restricted* and not *severely restricted* because % grade does not complicate the characteristics of this terrain. Following the IPB conducted above, the alternative being considered in terms of space available appears to be adequate for a large base camp. A scrutiny of the IPB conducted on the proposed piece of terrain indicates that though not continuous, at least 4 km^2 of usable terrain exists for the construction of a base camp. Because 4 km^2 (planning factor) exist, this site is capable of supporting a large base camp and therefore, by definition, any smaller sized camp as well.

4.4. Orientation of Doctrinal Template

Although the doctrinal template is displayed as being oval or football-shaped (see Figure 6: Doctrinal Template for Site Layout), the layout can easily be represented in many other closed forms (oval, circle, square, rectangle, or similar to any trapezoid). Because the area is longer than it is wide and because the main secondary road running into the area is oriented along a north-south line, the doctrinal template would be best matched to the terrain if placed approximately 90 degrees off of its axis. When situated, the doctrinal template's oval shape should be allowed to relax, so that it fills the available space.

4.5. Activity Placement

4.5.1. Aviation Assets

The aviation assets are best placed along the western edge of the riverbank on the east side of the area, along the Mrežnica River. The aviation assets would face the river, thereby assuring that no helicopter-borne munitions would face into the perimeter. Moreover, the eastern portion of the site provides plenty of open terrain and significant terrain features to facilitate helicopter take-off and landing. The aviation assets could not be positioned effectively on the western portion of the site because any uploaded munitions would face the secondary road that provides the site such excellent access.

Further, helicopters would travel (continually and undesirably) over the road during take-off and landing.

4.5.2. Headquarters

The headquarters elements of the base camp are best placed in the camp's center to maximize command and control. The center of the base camp appears to be approximately near the village of Lisice.

4.5.3. Ammunition Holding Area (AHA)

The AHA requires security (from potential enemies) and separation from the main portion of the base camp. This security and separation helps to ensure that force protection is maintained. There is always a danger of explosive things exploding or key logistical items like ammunition (Class V) being sought after by a potential enemy. The AHA could be placed either in the northeast or northwest of the area, but the northeast shall be preferred because it is slightly more remote from the center of the base camp (density of soldier and company support areas) and it is nearer the flight line (helicopters) which requires many of the heavier Class V supplies.

4.5.4. Contractor Area

The Contractor area is best placed in the southwest to south central portion of the area because it is afforded the best access to the secondary and primary roads and storage area. Moreover, such a placement of the contractor area prevents unnecessary penetration by routine delivery vehicles or local hires deep into portions of the camp. Preventing deep penetration into the camp promotes security and a higher quality of life for soldiers who are trying to call the base camp home.

4.5.5. Wastewater Treatment Facility

The Waste Water Treatment Facility is best placed in the southeast of the area where it has good road access for contractors, where it is close to water, and where it is far from the center of camp. The center of camp will house the density of soldier and company support areas.

4.5.6. Company Support Areas

Both company and soldier support areas will be largely collocated at the base camps center. The company support areas should be closer to the perimeter of the camp than should the soldier support areas. The company support areas will include activities such as, but not limited to, motor pools, personnel offices, supply rooms, and headquarters.

4.5.7. Soldiers Support Areas

Soldier support areas (specifically barracks) should always be away from the perimeter of a base camp to increase soldier force protection. Anytime barracks or heavily occupied soldier areas are near the perimeter, they become an easier target for snipers or for those who would park car or truck bombs just outside the perimeter. Therefore, the soldier barracks, in accordance with the doctrinal template and the natural characteristics of the site (apparent small change in elevation etc.) should be placed in the vicinity of Šušnjari and Jelovci. All of the other soldier support areas such as gyms, education centers, laundry drop-off points, mailrooms, post exchanges, etc. should be located in proximity to the barracks and company areas, but should be organized as a distinct and separate area (like a strip mall) from the sleeping and work areas.

4.5.8. Other facilities

Each base camp will have additional or specialized requirements for facilities such as detention centers. When placing these activities, terrain will dictate often what is feasible, but the rule of thumb still can be stated as: put things together that belong together, keep things apart that do not belong together, and if it doesn't matter, place as otherwise convenient.

Section 5. Future Work

The Base Camp Design research conducted during this year (and the previous year by extension) has done as much to uncover and suggest areas for future research as it has to provide tangible products to assist commanders and planners in selecting potential sites for basecamps and in laying out those basecamps. The suggested areas for future work are discussed in this section.

5.1. Methodology Validation

During the upcoming summer of 2002, DSE is deploying three teams of officers and cadets into three different Commander in Chief (CINC) Areas of Responsibility (AORs) to use the methodology outlined in Section 3 to help those commanders and planners determine a subset of potential good base camp locations. Further, these teams will share what those layouts could or should look like depending on the mission requirements. Specifically, one team will travel to East Timor which in the AOR of the United States Pacific Command (PACOM); one team will travel to Honduras, Belize, and Guatemala in the AOR of the United States Southern Command (SOUTHCOM); and one team will travel to Kosovo and Macedonia in the AOR of the United States European Command (EUCOM).

Upon completion of these three deployments, the three officers who led them will reconcile their findings and make changes to the proposed methodology contained in Section 3. Further, additional future summer deployments will be planned to ensure the methodology can be further tested and refined, and to ensure that CINCs continue to get usable products to help them site and layout basecamps.

5.2. Improve Decision Support System

The Decision Support System (DSS) is the analytical tool provided in the methodology of Section 3 that allows a commander or planner to select the best site from a list of candidate sites (alternatives). While this research has determined those values and underlying objectives that matter in choosing sites, it stopped short of eliciting the shape of the value functions from a subject matter expert (SME). In the DSS as constructed, the value functions are all currently

linear. This assumes that regardless of which single dimensional value is looked at (size for example), the value of one acre is the same whether that acre is gained by moving from one acre to two acres or 1000 acres to 1001 acres. This is probably not the true case and is therefore worthy of additional research.

The weights placed upon the objectives are also shown as equivalent in the DSS as constructed, but they can be easily and quickly obtained by using the swing weighting technique [Clemen]. Each decision maker must go through the swing weighting process to ensure his preferences are adequately captured and thus reflected in the model.

5.3. Implement Methodology in an Expert System

Once the methodology is refined through verification and field research, implementing it in an expert system would be an effective way to ensure that it is effective and useful to commanders and planners.

5.4. Harvest the Power of Geographical Information Systems

Though considered and evaluated as a peripheral activity while constructing the methodology, the power of geographical information systems was not fully explored. First, for much of the world, the data files are incomplete or of such low resolution that they do not provide the information needed to score alternatives using the Fundamental Objectives Hierarchy or to conduct risk mitigation using the Values Hierarchy. If one wants to find all of the branches of a particular coffee store in Atlanta, that can be done using Geographical Information Systems (GIS). However, if one is in East Timor, basic terrain relief data cannot be obtained. In a nutshell, the technology exists to use GIS as opposed to potentially dated paper maps to execute this methodology, but the necessary products do not…yet.

GIS products, however, can and should be an important part of the methodology presented in this report.

5.5. A Role in Deliberate and Crisis Action Planning

The methodology of Section 3 is destined to become shelf-ware like many other products if it does not carve out a niche for itself. A niche (in addition to the others alluded to throughout this report) for this methodology may be in doctrine or practice in conducting deliberate or crisis action planning. During the Basecamp Design Workshop hosted by DSE in September of 2002, a partnership was formed with one of its attendees, Commander Bob Wohlschlegel, J-38, PACOM.

This partnership has resulted in DSE attending one Multinational Planning Augmentation Team (MPAT) Conference in which nations in PACOM's AOR come together to conduct crisis action planning in response to a fictitious scenario. This particular MPAT Conference revolved around a disaster relief scenario in which over 100,000 people were displaced. Crisis action planning was conducted by the multinational participants which included an element of selecting sites to place about a dozen refugee camps. While refugee camps are not base camps, many of the same functions are required and the methodology of Section 3 provides a launching point for choosing these sites.

DSE is participating later this summer (2002) in a second MPAT conference in Singapore. A similar Humanitarian/Disaster Relief (HA/DR) Scenario will be addressed, so another chance to build "market share" for the site selection and facility layout methodology exists.

5.6. Further Leverage Simulation to Validate Site Layouts

During a portion of the research year, a team of capstone cadets worked to simulate Camp Bondsteel, a large and well-known basecamp, in ProModel, a simulation software package. The team did so successfully and showed how a simulation of the baseline camp could be used to compare statistics on the flow of entities around the basecamp. Modifications to the baseline camp, or completely different layout concepts can be constructed and modeled to determine if one layout is superior to another based on camp size, mission, terrain, etc. Further simulations would provide an additional valuable information regarding the strength of the current doctrinal template; in fact, simulation may be the only way to determine layouts as the number of potential distinct alternatives is virtually limitless.

5.7. Requirements Analysis

To avoid putting the cart before the horse, a thorough requirements analysis centering on what base camps of various sizes should do under varying missions and rules of engagement (ROE) would be useful. Currently, no such cornerstone document exists.

5.8. Integrate Cost into the Model

Cost is an ever-present concern in all decisions involving the commitment of resources. The methodology presented in this technical report focused on strictly the functionality of the system being designed. This cost should be considered more thoroughly and should be traded off against the cost of that functionality. Cost was intentionally left out of the original analysis because it is more a characteristic of the mission and location (uncontrollable constraints) rather than the alternatives. However, to assume that each alternative will have identical cost recurring or non-recurring costs is a mistake. A Pareto frontier showing how much value an alternative provides at what cost might provide an additional insightful look into what a good alternative might be. Further, cost could be integrated into the Value Hierarchy or Fundamental Objectives Hierarchy and directly measured as part of the DSS.

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Appendix A: List of Symbols, Abbreviations and Acronyms

AFCEA	Armed Forces Communications and Electronics Association
AHA	Ammunition Holding Area
AI	Area of Interest
AO	Area of Operations
AOR	Area of Responsibility
CINC	Commander in Chief
COE	Corps of Engineers
DR	Disaster Relief
DSE	Department of Systems Engineering
DSS	Decision Support System
DTIC	Defense Technical Information Center
EU	European Union
EUCOM	United States European Command
FARP	Forward Arming and Refueling Point
GIS	Geographical Information Systems
HA	Humanitarian Assistance
INCOSE	International Council on Systems Engineering
IPB	Intelligence Preparation of the Battlefield
MODA	Multi-objective Decision Analysis
MORS	Military Operations Research Society
MOUT	Military Operations in Urban Terrain
MPAT	Multinational Planning Augmentation Team
NATO	North Atlantic Treaty Organization
NGO	Non-governmental Organization
NTU	Nephlometric Turbidity Units
OOTW	Operations Other Than War
ORCEN	Operations Research Center
PACOM	United States Pacific Command
POL	Petroleum, Oil, and Lubricants
PVO	Private Volunteer Organization
ROE	Rules of Engagement
SASO	Support and Stability Operations
SE	Systems Engineering
SEDP	Systems Engineering Design Process
SME	Subject Matter Expert
SOUTHCOM	United States Southern Command
USMA	United States Military Academy

Appendix B: Additional Example Application of the Site Layout Methodology

Map Information

Map Edition 3-DMA; Series M709; Sheet # 2285 II; Scale – 1:50,000

Area Covered by Map: Former Yugoslavia (Plaški, Croatia)

A. Intelligence Preparation of the Battlespace (IPB) Area A

Since the area boundaries are already drawn, the micro-IPB (or site specific IPB) can be conducted for Area A.

a. Elevation change analysis.

Area A is bounded to the north by the southern portion of a mountain named Debela Glava with an elevation of 384 meters. The majority of this mountain lies just to the north of Area A, but provides a commanding view of it. In the southwest corner of the area, there is a several hundred square meter depression near (just south of) the city of Gržani. In the eastern portion of the area, a hilltop named Mačkova Glavica peaks at 353 meters and is benchmarked. The center of Area A also contains a couple of other small, but unbenchmarked hilltops. The south central and southeastern portions of the area are also marked by a series of ridges which while, not extreme points of elevation within Area A, are the final indicators that Area A is the southern portion of a small plateau called Crno Osovje sitting just to the north of a dozen villages in a river valley to the south.

In general, the change in elevation in the central portion of Area A is small and not greater than 20 meters within any one 1000-meter grid square. However, in the extreme north and south of the areas, the elevation change is more substantial, sometimes as great as 15%. Therefore, this piece of ground, while suitable, may not be the best choice for a base camp location. At this point, however, Area A should not be thrown-out as a potential site due to grade. (Some slope is absolutely necessary to ensure that the ground drains properly.) The area located in the north and central of the Area A show the most promise from an elevation perspective.

b. Foliage analysis

The entire area under consideration includes about 5-6 square kilometers. Approximately 90% of this area is woodland and scrub brush. The two main forested areas include the area east and south of the city of Rupa and the area surrounding the city of Gržani located and all the area surrounding the mountain peak of Mačkova Glavica located at 466015.

While the total area covered by woods or bushes accounts for 90% of the area, there remains a small number of square kilometers on which to build a base camp. To avoid having to clear too much land at a great time and money cost, attention will have to be paid to the placement of the base camp facilities in relation to the wooded areas. For anything larger than a small base camp or Forward Arming and Refueling Point (FARP), significant numbers of trees will have to be cleared. Further, because clear land is associated with better force protection (in general), concern will have to be given to the threat posed by the mobility corridors and avenues of approach concealed by any remaining wooded areas.

c. Water analysis

Site A does not have a water source running through it. A sufficient water source is located approximately 2 km west of the area. Additionally, because other ways of obtaining water on site such as drilling wells or flying in water do exist, Area A should not be eliminated from further consideration.

d. Accessibility Analysis

1) Air accessibility

Because Area A is 90% wooded it contains numerous obstacles to air avenues of approach. Also, just to the south and east, only about 100 meters from the southeastern edge of Area A, there is a substantial power line run. Further, the previously discussed mountain in the northern portion of Area A creates an undesirable air obstacle. Further, and to a lesser extent, the heavily wooded areas in Area A are probably home to numerous species of birds, which in significant numbers or flocks can become air obstacles.

2) Road accessibility

To the west and north east, the area has access to two or more lane-wide, all weather, hard surface roads. In addition, there is a fair (or dry weather) loose surface road cutting across the southwestern portion of the area that provides access to that southwestern portion of Area A. This minor road "cuts the corner" of Area A and serves to connect the primary road in the west

to the primary road in the southeast. Area A has an extremely generous amount of road accessibility which will be key in determining potential layouts.

B. Space Availability Analysis

Area A is heavily wooded. Because these wooded areas can be cleared if necessary, the ones not complicated by slope restrictions have been classified as *restricted.* Those wooded areas that are complicated by excessive slope (greater than 8%) have been graded as *severely restricted* because % grade sufficiently complicates the characteristics of this terrain. The north and center portion of Area A has patches of flat area, which if cleared, can be used. The most usable portions of this area are in the Drenovac area located at 460020.

A scrutiny of the IPB conducted on the proposed piece of terrain indicates that though requiring significant tree clearing, at least 2 km^2 of usable terrain exists for the construction of a medium base camp.

C. Orientation of Doctrinal Template

Although the doctrinal template is displayed as being oval or football-shaped (see doctrinal template), the layout can easily be represented in many other closed forms (oval, circle, square, rectangle, or similar to any trapezoid). Because Area A is longer than it is wide and because the main secondary road running into the area is oriented along a western line, the doctrinal template would be best matched to the terrain if placed approximately 170 degrees off of its axis for our location.

D. Activity Placement

a. Aviation Assets

The aviation assets are best placed along the south eastern edge of the area on the eastern side of the area facing away from the city of Kurst and south eastern portion of area 2 away from the primary and secondary roads located in the far east and western borders of our area. The aviation assets would face the outskirts of the areas away from the major roads and cities, Rupa and Kurst, thereby assuring that no helicopter-borne munitions would face into the perimeter. Moreover, the southern portion of the site provides plenty of flat open terrain to facilitate helicopter take-off and landing. The aviation assets could not be positioned effectively on the northern portion of the site because of the inaccessible due to telephone lines and high mountain tops. In addition, we would not place our aviation assets towards the secondary road that

provides great mobility to our south. Further, helicopters would travel (constantly and undesirably) over the road during take-off and landing.

b. Headquarters

The headquarters elements of the base camp are best placed in the camp's center to maximize command and control. The center of the base camp appears to be approximately 0.5 km from the village of Rupa and in the center of the two small hilltops.

c. Ammunition Holding Area

The ammunition holding area would be isolated not facing the major roads. It would be placed to the Northern part of the template to minimize any collateral damage in case of an accident.

d. Contractor Area

We would place the contractor area to the very southern tip of the base camp next to the road. This is done to facility the transportation of supplies in and out of the base camp by the contractors and at the same time to minimize "outside" people walking through the middle of our area of operations.

e. Wastewater Treatment Facility

We want to try an isolate this facility to minimize any discomfort the treatment facility might bring to the soldiers. This could be done by isolating the facility to the Eastern side relative to the template.

f. Company support areas

Company support areas should also be isolated as much as possible to once again minimize and disturbances that they can cause the soldiers. The company support areas could be placed near the Western border.

g. Soldiers support areas

Soldier support areas (specifically barracks) should always be away from the perimeter of a base camp to increase soldier force protection. Anytime barracks or heavily occupied soldier areas are near the perimeter, they become an easier target for snipers or for those who would park car or truck bombs just outside the perimeter. Therefore, the soldier barracks, in accordance with the doctrinal template and the natural characteristics of the site (apparent small change in elevation, etc.) should be placed in the middle of our area of operations.

h. Other facilities

Other support facilities should be distributed within the area of operation depending on what category they fall under. For instance, the motor pool is part of company support so it should be placed in a similar manner as described above.

Appendix C: Decision Support System

Appendix C shows how the site selection portion of this methodology is accomplished in MS Excel. Figure 8: The Excel-based Decision Support System has three distinct sections: a top section, a center section, and a bottom section. In the top section, the alternatives shown as Sites A through I are scored using Figure 5 according to the methodology outlined in Section 3. In the center section of Figure 8, the alternatives scores are normalized (on a linear scale in this case). Under the center section a row of weights (which are currently shown as being equal at 0.143) are multiplied by the center table to obtain the bottom section of Figure 8. The bottom section of the table represents the weighted values of each alternative in each evaluation measure. The row sums (for each alternative) are then shown (italicized)to the far right in the bottom section of Figure 8. This column is entitled "Alternative Value" and these numbers are used to rank order the alternatives from most to least preferred with higher values being better.

Site Selection Decision Support System

Evaluation Measure / Alternative	Size (square kilometers)	Air Access constructed	Road Access constructed	Slope (rise/run); dimensionless	Foliage constructed	Distance to Water Source (kilometers)	Distance to Mission Area (kilometers)	
Site A	6.5	0	21	6	10	3	18	
Site B	17	3	35	1	1	0	14	
Site C	9	0	27	1	7	1.5	21	
Site D	7	0	59.5	1	9	1	26	raw data
Site E	15	3	40.5	7	1	5	16	
Site F	8	0	15.5	9	2	0	8	
Site G	8.5	0	34	5	7	1	11	
Site H	14.5	1	52	2	4	2	24	
Site I	7.5	2	39	2	2	1	30	
best value	17	3	59.5	1	1	0	8	
worst value	6.5	0	15.5	9	10	5	30	

Evaluation Measure / Alternative	Size (square kilometers)	Air Access constructed	Road Access constructed	Slope (rise/run); dimensionless	Foliage constructed	Distance to Water Source (kilometers)	Distance to Mission Area (kilometers)	
Site A	0	0	0.125	0.375	0	0.4	0.545454545	
Site B	1	1	0.443181818	1	1	1	0.727272727	
Site C	0.238095238	0	0.261363636	1	0.333333333	0.7	0.409090909	
Site D	0.047619048	0	1	1	0.111111111	0.8	0.181818182	utility
Site E	0.80952381	1	0.568181818	0.25	1	0	0.636363636	
Site F	0.142857143	0	0	0	0.888888889	1	1	
Site G	0.19047619	0	0.420454545	0.5	0.333333333	0.8	0.863636364	
Site H	0.761904762	0.333333333	0.829545455	0.875	0.666666667	0.6	0.272727273	
Site I	0.095238095	0.666666667	0.534090909	0.875	0.888888889	0.8	0	
weights	0.143	0.143	0.143	0.143	0.143	0.143	0.143	1.000

Evaluation Measure / Alternative	Size (square kilometers)	Air Access constructed	Road Access constructed	Slope (rise/run); dimensionless	Foliage constructed	Distance to Water Source (kilometers)	Distance to Mission Area (kilometers)	
Site A	0	0	0.017857143	0.053571429	0	0.057142857	0.077922078	[illegible]
Site B	0.142857143	0.142857143	0.063311688	0.142857143	0.142857143	0.142857143	0.103896104	[illegible]
Site C	0.034013605	0	0.037337662	0.142857143	0.047619048	0.1	0.058441558	[illegible]
Site D	0.006802721	0	0.142857143	0.142857143	0.015873016	0.114285714	0.025974026	[illegible]
Site E	0.115646259	0.142857143	0.081168831	0.035714286	0.142857143	0	0.090909091	[illegible]
Site F	0.020408163	0	0	0	0.126984127	0.142857143	0.142857143	[illegible]
Site G	0.027210884	0	0.060064935	0.071428571	0.047619048	0.114285714	0.123376623	[illegible]
Site H	0.108843537	0.047619048	0.118506494	0.125	0.095238095	0.085714286	0.038961039	[illegible]
Site I	0.013605442	0.095238095	0.076298701	0.125	0.126984127	0.114285714	0	[illegible]

Figure 8: The Excel-based Decision Support System

Appendix D: Distribution List

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